CAPSTONE ENTERPRISES WEST, LLC
GEOTECHNICAL AND MINING ENGINEERING
TESTING AND INSPECTION SERVICES

618 PARTEE DRIVE
GRAND JUNCTION, CO 81504
PHONE (970) 250-3331
capstonewest@juno.com

Attention: Mansel Zeck
Innovation Homes
1119 N1st St, Suite 1
Grand Junction, CO 81501

6/13/16

Subject: Foundation Recommendations
Bella Dimora Subdivision
Legends Way and Patterson
Grand Junction, CO 81504

As per your request, Capstone Enterprises West, LLC (Capstone) has prepared this report detailing foundation recommendations for the Bella Dimora subdivision. As part of this work, Capstone reviewed the previous geotechnical reports prepared for the Legends Development and obtained samples for laboratory testing to make recommendations for foundation construction for the latest phase of development.

SITE DESCRIPTION

The USGS has mapped almost the entire area to be developed as the Legends as (Km) Mancos Shale (a portion of the USGS map is presented on the following page. The base map for the USGS appears to be from the late 1970's or early 1980's, based on the extents of development in the area. Even at that time, a fair number of houses had been constructed on the Mancos Shale.

The next figure shows extents of the Mancos Shale that were transferred onto a Google Earth image (cross hatched in yellow) of the area surrounding the Legends. This image shows significant development on the Mancos. The majority of the development south of Patterson Road is the Legends and the development north of Patterson is the Indian Creek Subdivision. While the geology south of the Grand Valley Canal is mapped as Alluvium, the foundations of many of these homes is directly on the Mancos.

There is one very important point that needs to be made here, the Mancos Shale Formation is approximately 4,000 thick; from its lower contact on the south side of the valley near the Spyglass development to the upper contact on the north side of the valley near the top of Mount Garfield.

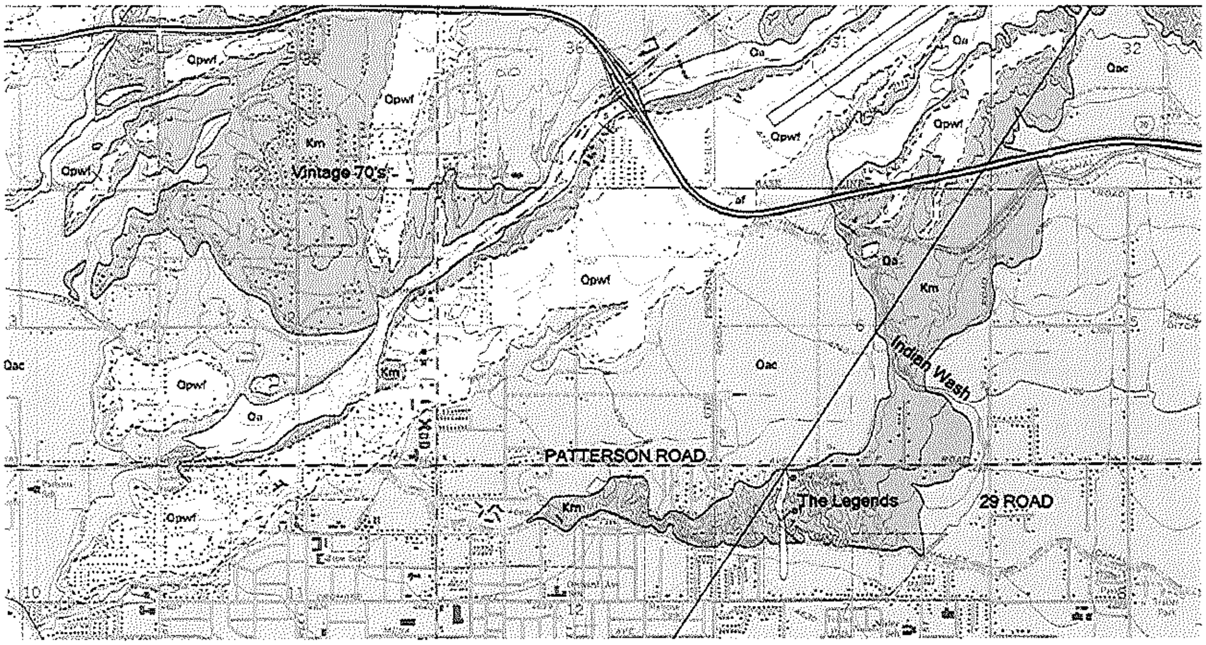


Figure 1 – A portion of the USGS geologic map of the Grand Junction Quadrangle.

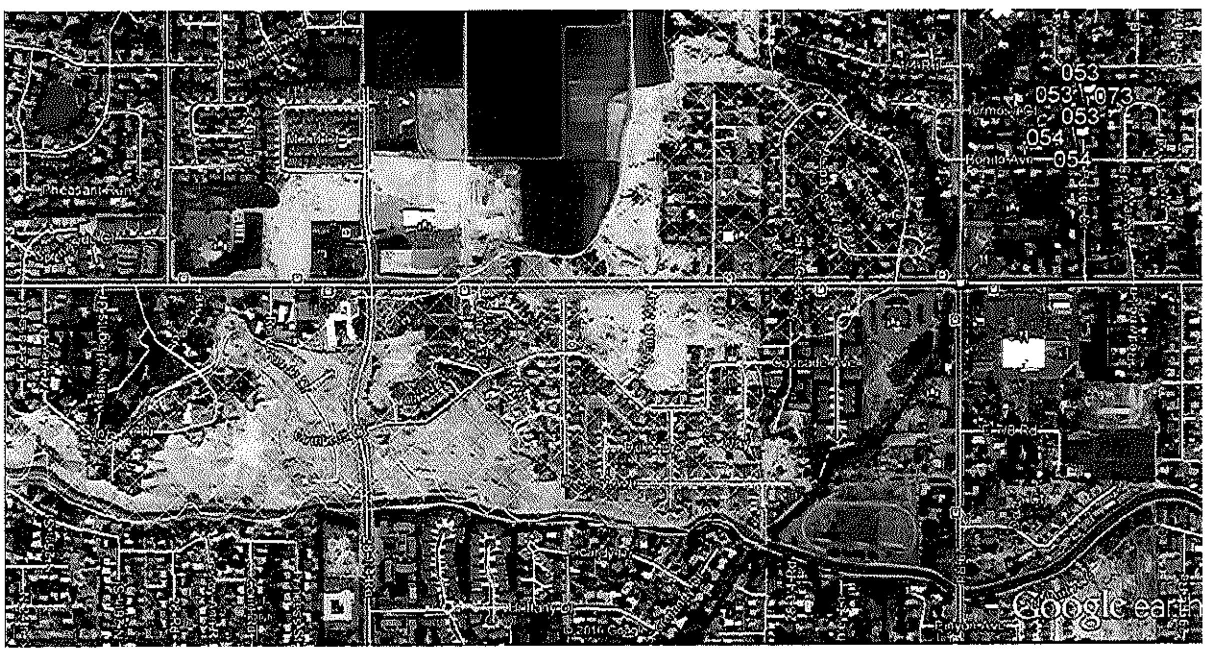
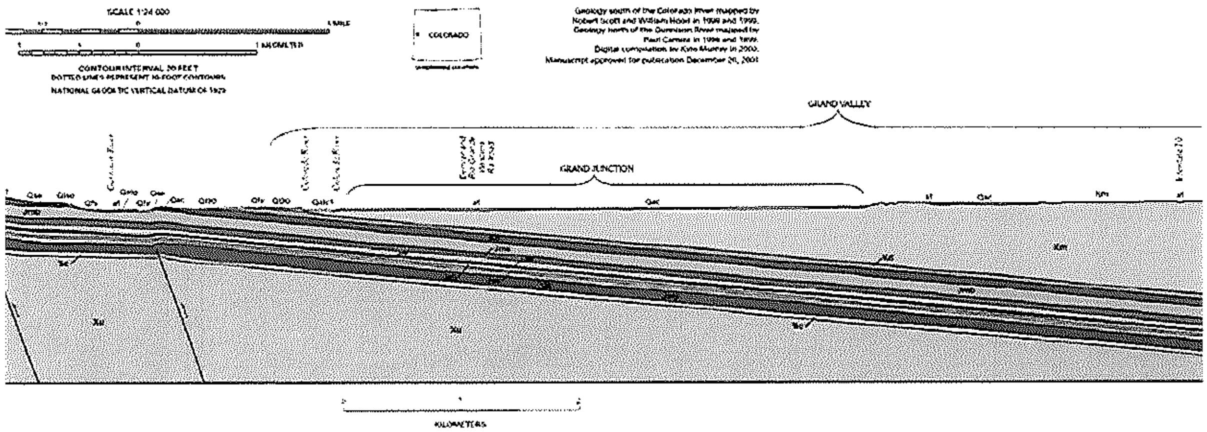


Figure 2 – USGS extents of the Mancos Shale surface exposures transferred to a Google Eart image.

Figure 3 is a cross sectional view across the valley showing the extents of the Mancos Shale. Over the approximately 20 millions years it took to deposit the 4,000 feet of sediment volcanic activity in the area deposited ash in the mancos that produced bentonitic clays at times. Changes in currents within the depositional basin changed gradations resulting in sandy layers and clayey layers. The more clayey the source sediments the more prone to weathering and potential swelling.



GEOLOGIC MAP OF THE GRAND JUNCTION QUADRANGLE, MESA COUNTY, COLORADO

By

Robert B. Scott[1], Paul E. Carrara[1], William C. Hood[2], and Kyle E. Murray[1]

2002

Survey, Denver, CO 80225
Grand Junction, CO 81503

Figure 3 – Cross-section across the valley showing the extents of Mancos Shale (Km)

The wide range in gradiation over the 4,000 feet vertical thickness outcroping across the 10 miles along the valley floor results in drastically different structural properties of the Mancos at different sites.

Similar shale formations exist across the county and the Federal Highway Administration prepared a report detailing construction problems associated with shales entitled, "Design and Construction of Compacted Shale Embankments" (1975). A major finding in the report was how the stregnth variation in layers of shale was a contributing factor to a number of embankment failures. During the construction process, fresh exposures of shale can be very strong; however, over time these strong blocks weather. If the strong blocks had rock on rock contact with insufficient fines to fill the voids in between, settlement will occur over time. The following photo shows how this pheomenon appears at the surface.

Figure 4 – Problematic shale gradation, large hard block too few of fines

A cursory inspection of houses built directly on Mancos in the Indian Creek area showed a fair number of driveways exhibiting distress most likely from a consolidation problem rather than a swelling issue. The the water that runs off the sides of the driveways causes the edges to settle and the driveways deform with an arch in the middle, not a trough that would result from swelling near the edges.

To evaluate the subgrade properties for this development, 7 test pits were excavated at the Bella Dimora site Figure 5 shows the locations of the excavations, followed by the geologic logs.

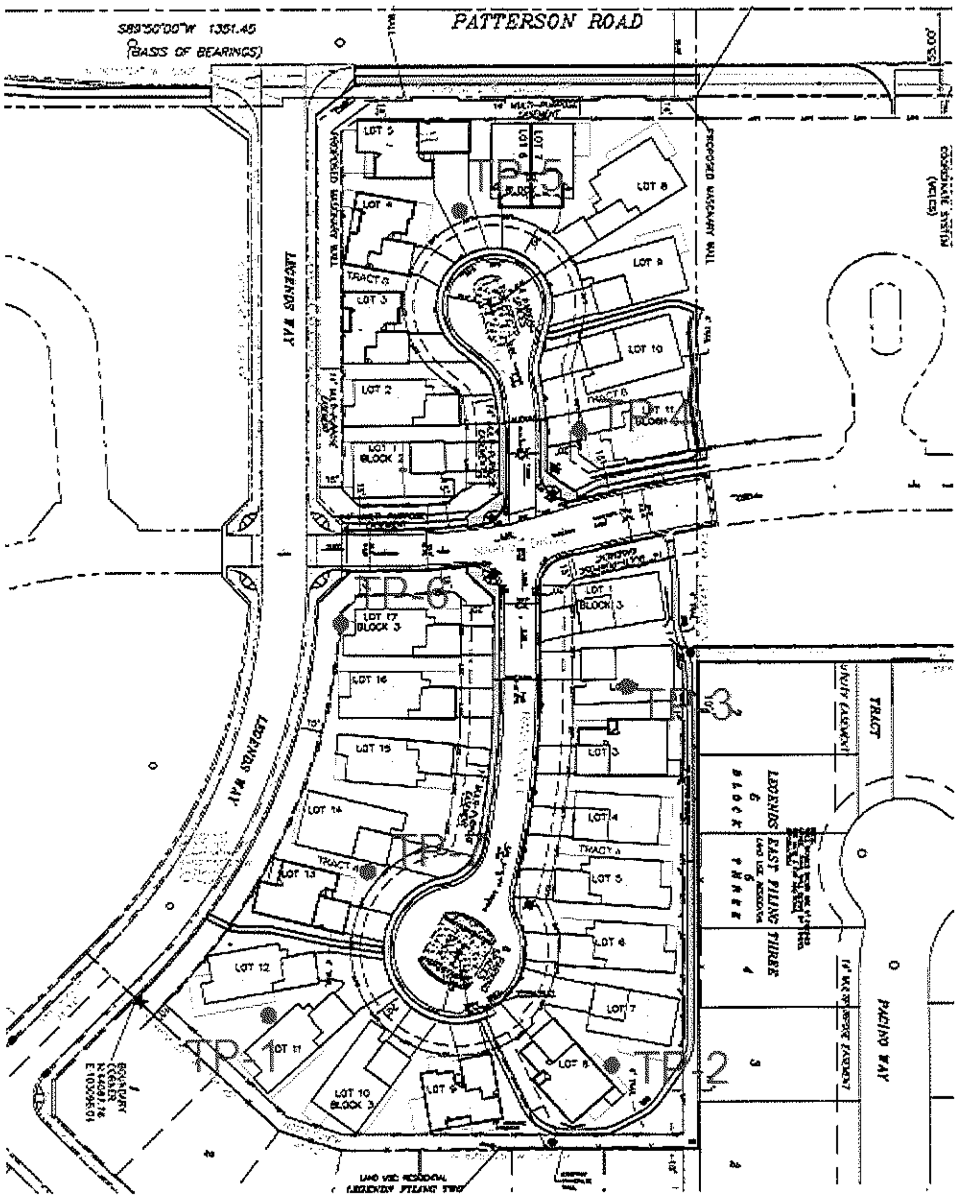
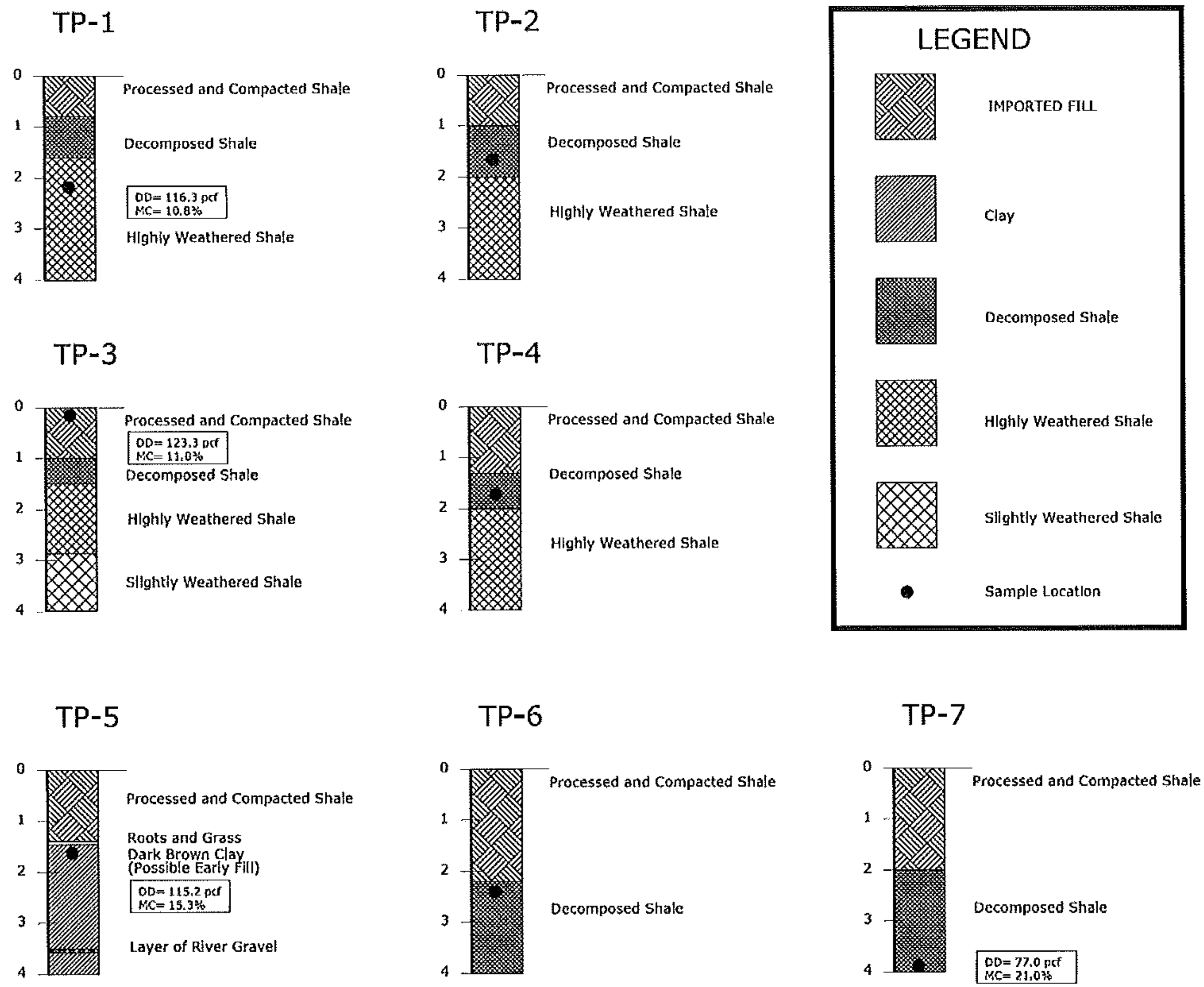


Figure 5 – Test Pit Locations



TP-1
0
1
2
3
4
Processed and Compacted Shale
Decomposed Shale
DD= 116.3 pcf
MC= 10.8%
Highly Weathered Shale
TP-2
0
1
2
3
4
Processed and Compacted Shale
Decomposed Shale
Highly Weathered Shale
LEGEND
IMPORTED FILL
Clay
Decomposed Shale
Highly Weathered Shale
Slightly Weathered Shale
Sample Location
TP-3
0
1
2
3
4
Processed and Compacted Shale
DD= 123.3 pcf
MC= 11.0%
Decomposed Shale
Highly Weathered Shale
Slightly Weathered Shale
TP-4
0
1
2
3
4
Processed and Compacted Shale
Decomposed Shale
Highly Weathered Shale
TP-5
0
1
2
3
4
Processed and Compacted Shale
Roots and Grass
Dark Brown Clay
(Possible Early Fill)
DD= 115.2 pcf
MC= 15.3%
Layer of River Gravel
TP-6
0
1
2
3
4
Processed and Compacted Shale
Decomposed Shale
TP-7
0
1
2
3
4
Processed and Compacted Shale
Decomposed Shale
DD= 77.0 pcf
MC= 21.0%

LABORATORY RESULTS

The suitability for foundation material is generally determined by two tests: the Swell/Consolidation test and the Atterberg Limits test. The Swell/Consolidation test consists of placing an undisturbed sample of material in a device that applies a load to the soil. The specimen compacts or "consolidates". After the initial load stabilizes, the specimen is saturated, and the specimen will either swell or consolidate further. There were 5 general classifications of soils on the site:

- Processed and compacted shale (native and import)
- Decomposed shale
- Highly weatherd shale
- Sightly weathered shale
- Clay (origin unknown, possible old fill)

Initially 4 samples were selected for the Swell/Consolidation test 2 decomposed shale (TP-1 and TP-7), the processed and compacted shale (TP-3) and the clay (TP-5). The plots of the tests are presented on the following pages.

The processed and compacted fill from TP-3 was the only sample that showed a swell pressure (1,400 psf), the clay from TP-5 exhibited swell potential on the rebound portion of the test but no significant pressure.

Since the site is going to require significant import to meet the grading requirements, the imported fill was also tested. First an Atterberg Limits test was run on a composite sample taken from the stockpiled material on site June 1, 2016.

The Atterberg Limits Test gives an indication of the mechanical properties of fine grained materials. The first part of the test is to determine the Plastic Limit of the material. Then the Liquid Limit is determined. The difference between the Liquid Limit and the Plastic Limit is defined as the Plasticity Index. Swell potential based on the plasticity limit (PI) are shown below.

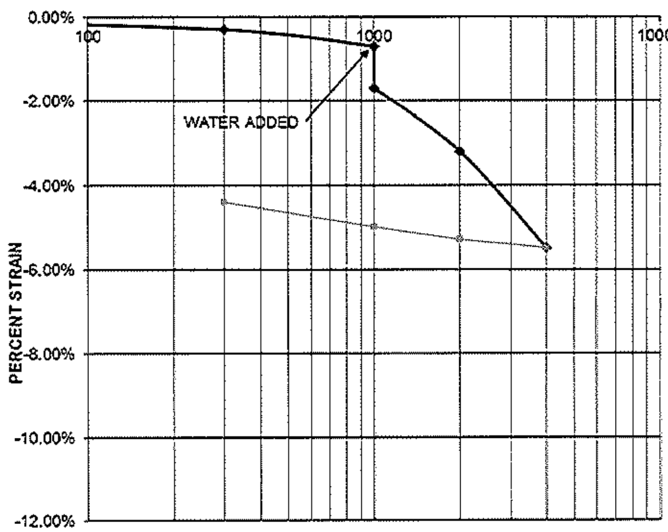
Plasticity Index (PI)	Inherent Swelling Capacity
0-15	Low
10-35	Medium
20-55	High
35+	Very High

(After Seed et al. 1962)

The composite sample of imported shale had PI of 14, indicating low swell potential.

Bella Dimora
TP-1 @ 2'

CONSOLIDATION TEST REPORT

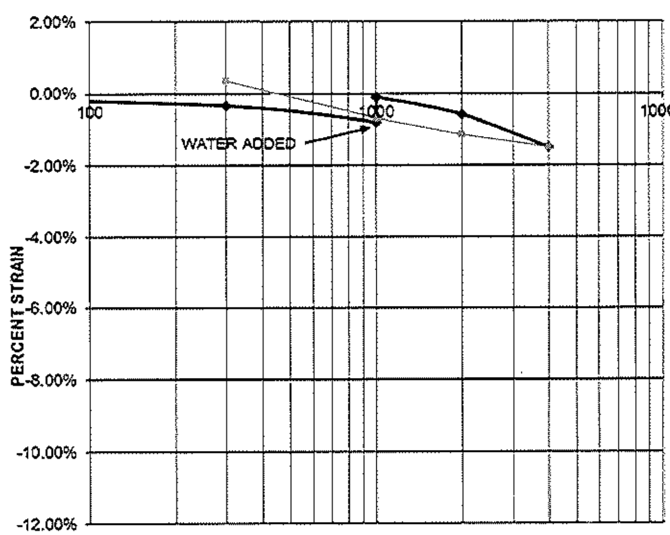


Weathered Shale
Dry Density 116.3 pcf
Natural Moisture 10.8%

Job No. 3963

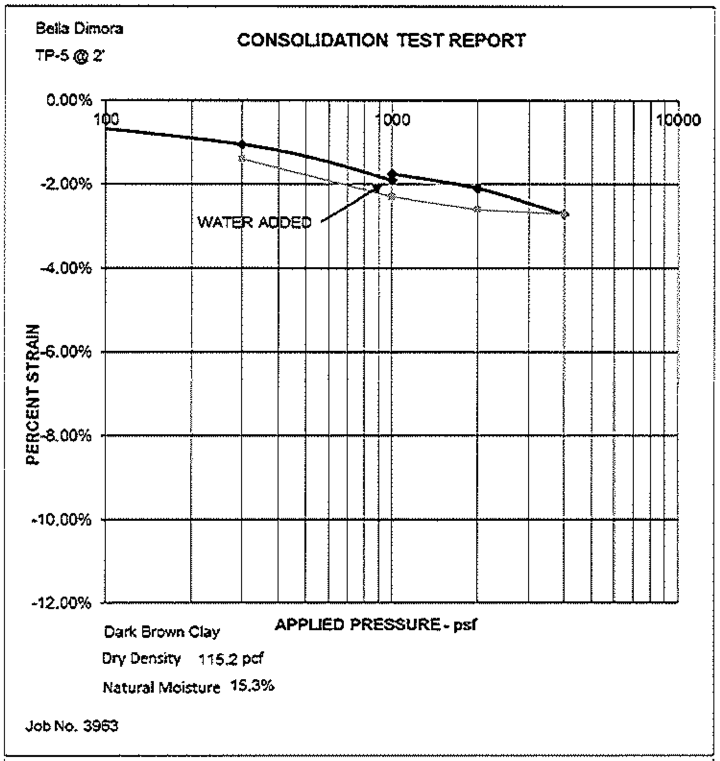
Bella Dimora
TP-3 @ 0.1'

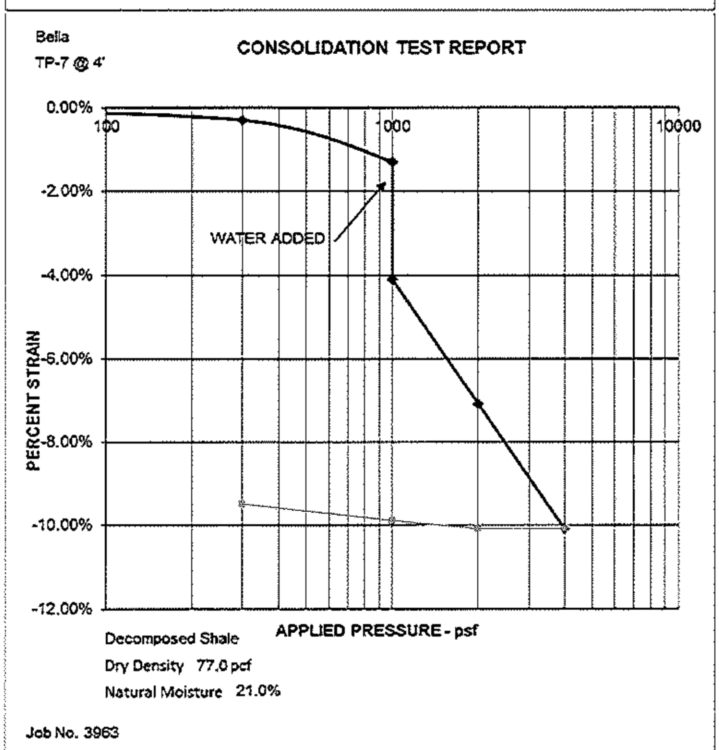
CONSOLIDATION TEST REPORT



Compacted Native
Dry Density 123.3 pcf
Natural Moisture 11.0%

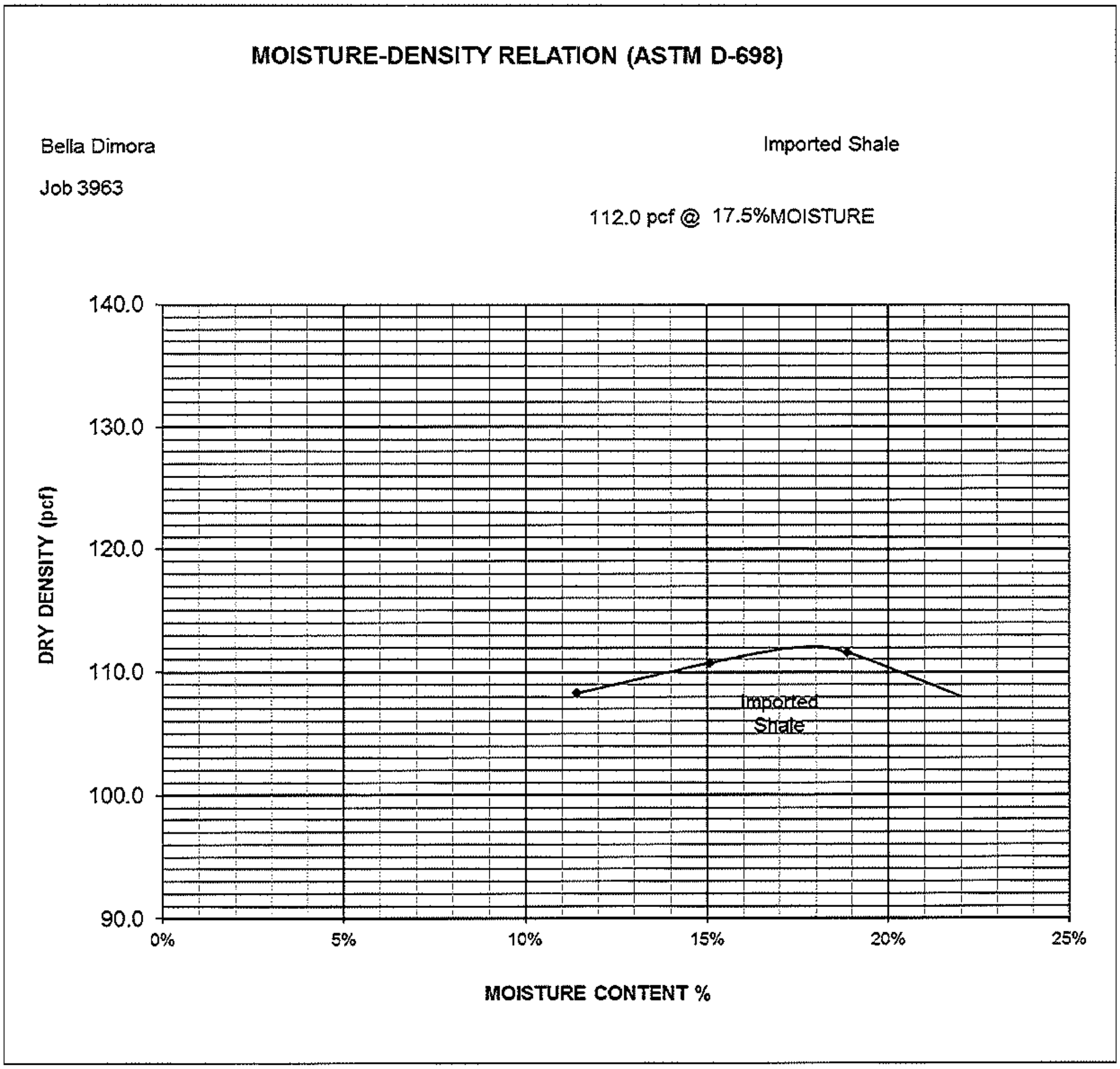
Job No. 3963



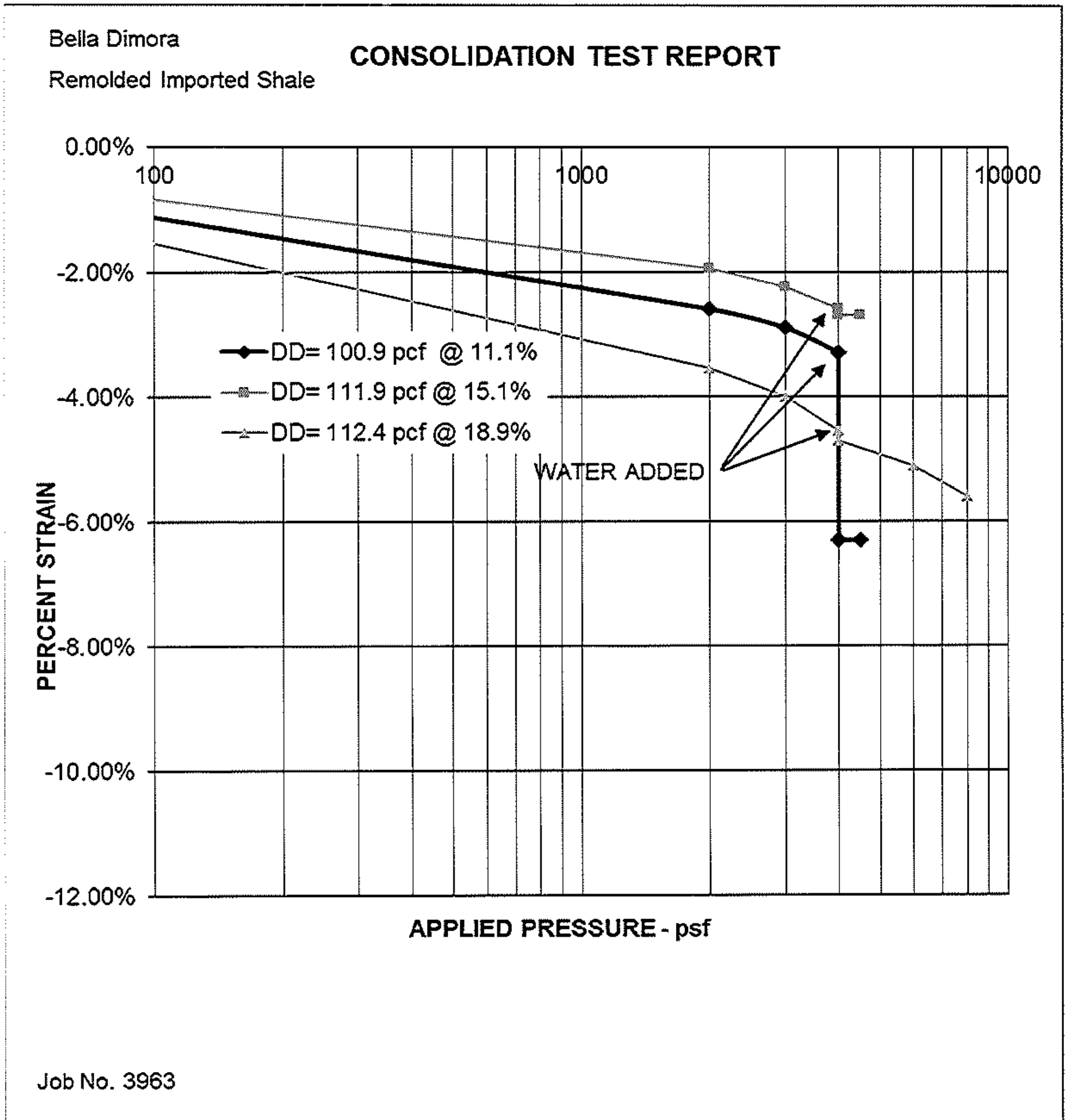


Based on the grading requirements the imported shale will play a large role on the type of foundations used for this development. The strength of soils and aggregates is a function of their density. The denser a given material is, the stronger it is. The maximum dry density of a material is determined by running an

ASTM D-698, Moisture-Density Relation Test. This is commonly called the Standard Proctor Test. Samples with different moisture contents are compacted with equal forces and a curve of the moisture density relationship is established. The following graph shows the moisture density relationship for the imported shale.

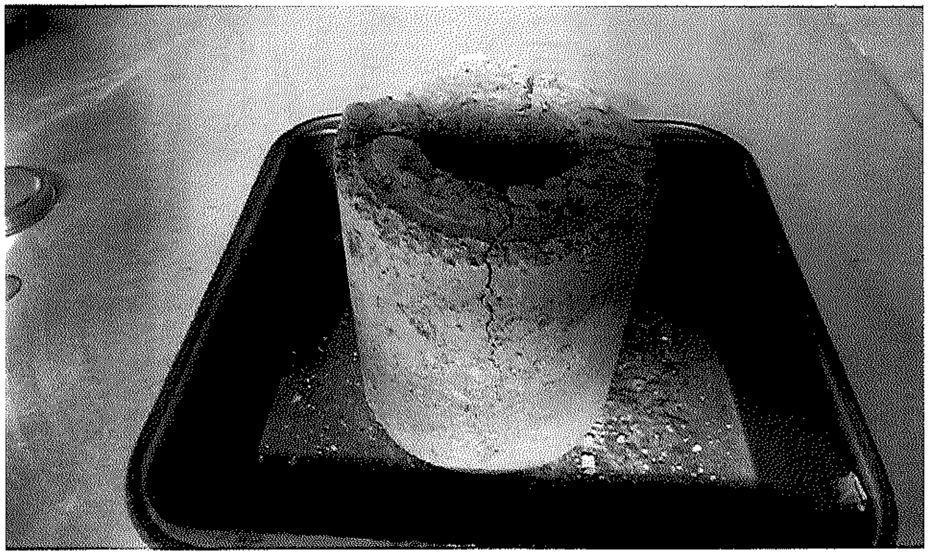


To determine how the imported shale will perform once it is compacted, samples from the 3 points on the proctor curve were subjected to the Swell/Consolation test. The results for all are plotted on the same chart (presented of the following page).

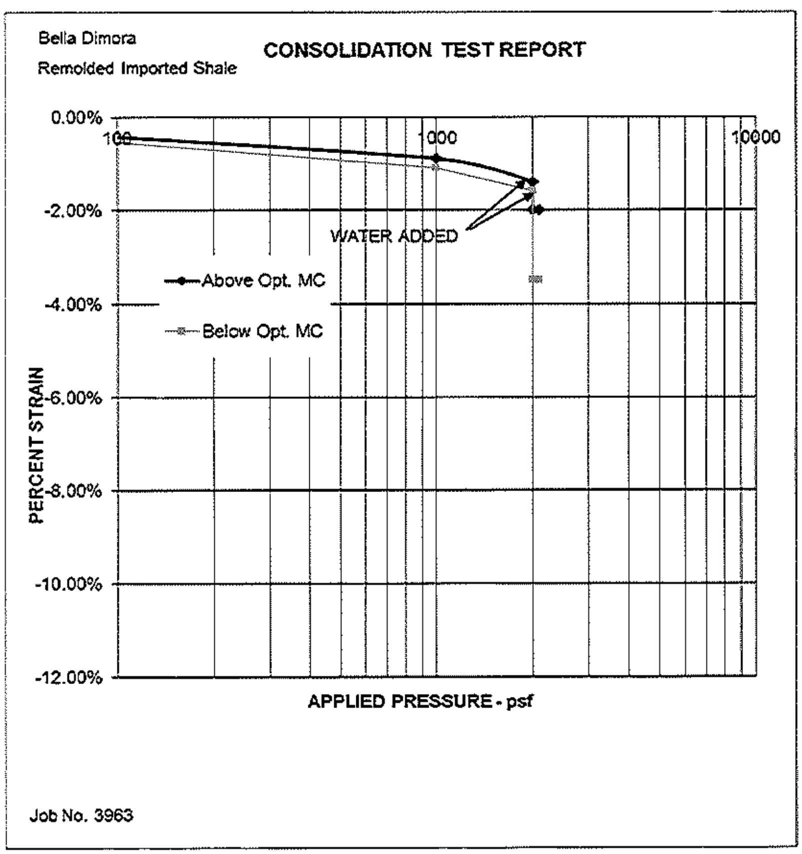


From this chart it can be seen that two points nearest to Optimum moisture performed the best. While the dry sample was firmer while dry, the voids between the solids allowed for excessive consolidation when saturated. This is similar behavior to the embankment failures; without sufficient moisture during the compaction phase to aid the small fragment in moving between the large fragments, air voids are produced. These air voids allow water to move freely through the sample reducing the friction between fragments and resulting in collapse. Proper moisture during compaction is critical for long term performance.

A concern with placing fill on the high side of optimum is how it will behave once is dries out and then becomes saturated. To explore that question, remolded samples were prepared using the proctor process, then the samples were dried in an oven at 100 degrees for 24 hours. A sample was obtained from the center of the proctor cylinder for testing in the Swell/Consolidation apparatus. The following photo shows the sampling technique.



Only the two points near optimum were tested the results are presented below.



Once again the sample compacted at above optimum moisture performed the best.

FOUNDATION RECOMMENDATIONS

From the previous geotechnical investigations, the maximum swell pressure exhibited by the shale in the Bella Dimora subdivision was 1,200 psf. The material tested by Capstone had a maximum swell pressure of 1,400 psf. Based on the typical foundation loads for a single family residence these swell pressures are considered relatively low. However, since this swelling can occur at some depth below the foundation consideration must be given to that possibility. Three types of foundation are suitable for this development:

- High dead-load wall on grade or voided wall on grade
  - Subgrade processed and moisture conditioned +1/+2% above optimum
  - One foot structure fill compacted
  - Minimum deadload 2,000 psf
  - Maximum bearing load 4,000 psf
  - Loads to be balanced within 10%
- Slab on grade with 2 feet Structural fill
  - Subgrade processed and moisture conditioned +1/+2% above optimum
  - Two feet structure fill compacted
  - Slab to be constructed as a structural slab
- Micropiles
  - 15-20 foot deep
  - 5 feet un-bonded length
  - Void under grade beam

From site visits and conversations with the contractor, Capstone understands that the amount of imported fill will be significant. Therfore, the cost of each foundation system must account for the backfill and grading. On the following page sketches of each foundation are presented in Figure 6. The different types of fill are hatched and colored differently.

Based on a house footprint of 2,300 sqare feet (including garage), the cost of each foundation system was estimated using current aggregate prices from Parkerson's and concrete from Whitewater. For the cost of backfill and concrete alone there is a $5,500 savings to use the wall on grade foundation system rather than a slab on grade. While the micropile foundation requires the least amount of earthworks and backfill, the total cost of the micro piles would have to be approximately $5,000 per residence to match the cost of the wall on grade.

Based on the performance of the subgrade materials, the imported fill and the grading requirements; Capstone recommends thet the residences at Bella Dimore be founded on wall on grade foundations design to provide a minimum of 2,000 psf deadload and a maximum bearing load of 4,000 psf. The design loading should be balanced within 10%, this may require void form in areas. The foundation subgrade should be moisture conditioned (+1% to +3% above optimum) and compacted to greater than 95% of the Standard Proctor. This native/imported subgrade should be covered with a minimum of 12 inches of granular non-freedraining aggregate (Parkerson's ¼" minus or equivalent as approved by the engineer). This is to distribute the foundation load more evenly and protect the subgrade from desiccating.

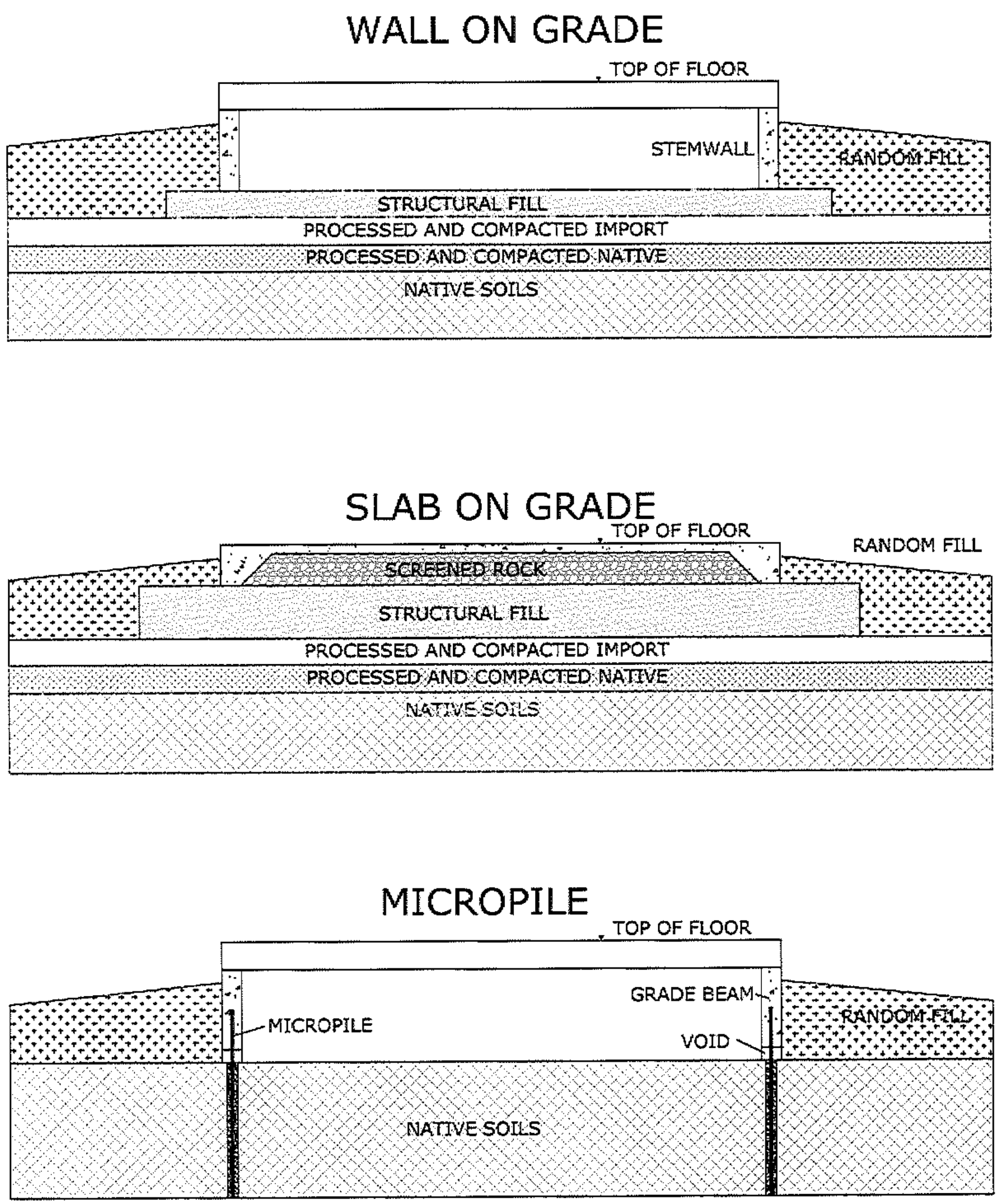


Figure 6 – General Arrangements of Foundation Options

DRIVEWAY CONSTRUCTION

As noted earlier driveways in this area are more prone to distress due largely to poor subgrade conditioning. Therefore, Capstone recommends that that subgrade be prepared the same as the foundation; moisture condition and compact the subgrade a minimum of 12" deep, cap with angular aggregate a minimum of 12" (compact to 95% Modified Proctor +1/-1% optimumm moisture). To maintain the service life of the concrete, the slab should be rebar reinforced. For garage slabs the structural fill should be a minimum of 24" deep or the slab be constructed with a void below.

GRADING CONSIDERATIONS

From these tests the imported shale is a suitable subgrade for foundation construction provided the mass is properly moisture conditioned and compacted. Proper moisture conditioning for this imported shale should be 1% to 2% above optimum (exhibiting slight pumping during compaction). Compaction should be with a sheepsfoot roller to break up larger fragments and make a more homogeeous blend. It would be most cost effective if multiple adjacent lots be graded as one large lot.

A key feature in any foundation system is to minimize the potential of water ponding on soils with swelling or consolidating potential. If the structural fill is placed in an excavation, this is sometimes referred to as creating a bathtub. To avoid this, Capstone recommends that the final grade of the processed and compacted imported fill be sloped away from the foundation and only the structural fill be placed level.

WATER SOLUBLE SULFATES

The Soil Conservation Service's soil types reported a maximum of 15% gypsum, and gypsum crystals were observed in the test pits. This concentration of water soluble sulfates represents a severe degree of sulfate attack on concrete exposed to these materials. Based on this observation, sulfate resistant cement (Type II modified) should be used in all concrete exposed to the shale based soils. The high gypsum content can also resulting settling if the gysum is put into solution by groundwater. This is another reason to properly condition and compact the native subgrade over the entire lot.

FOUNDATION BACKFILL

As the density of soils affects their strength it aslo effects the permeability. The denser the material to lower the permeability and the less likely surface water will migrate through the fill. Compacting the backfill outside of the foundation is a critical step in maintaining a dry foundation. The compacted surface should always be away from the structure with the highest compactive effort nearest the foundation.

DRAINAGE AND IRRIGATION

The success of shallow foundation and slab-on-grade floor systems is contingent upon keeping the sub grade soils at more or less constant moisture content, and by not allowing surface drainage a path to the subsurface. Positive surface drainage away from the structures must be maintained at all times. Landscaped areas should be designed and built such that irrigation and other surface water will be collected and carried away from foundation elements. The final grade of the foundation's backfill and any overlying concrete slabs or sidewalks should have a positive slope away from the foundation walls on all sides. We recommend a minimum slope of 8" in the first ten feet; however, the slope can be decreased to 3" in ten feet if the ground surface adjacent to the foundation is covered with concrete slabs sidewalks or pavement.

As much as practical, we recommend, landscaping vegetation that is common to semi-arid climates, with low moisture requirements. A "drip" system of watering could be utilized to keep water usage low. Dry-type landscaping is encouraged.

Areas close to foundation elements, where snow will drift and accumulate, should be protected from standing water during periods of snowmelt.

Landscaped areas should be placed away from the foundation elements, and be designed to drain surface runoff away from the foundation elements.

The structure should have a rain gutter system that directs water away from the foundation elements.

The potable water supply should be located with sand protection of the line, in conjunction with clean gravel prior to backfilling, would provide a drainage path for water in the event of a waterline leak, away from the foundation.

LIMITATIONS

Based on our subsurface investigation, there were no geologic conditions that would prohibit the development of this property as proposed.

The analysis and recommendations submitted in this report are based on the test excavations, field observations and laboratory testing. The nature and extent of variation may not become evident until construction. If variations then appear, it will be necessary to reevaluate the recommendations in this report.

It is recommended that the geotechnical engineer be provided the opportunity for general review of the final design and specifications in order that earthwork and foundation recommendations may be properly interpreted and implemented in the design and specifications. It is also recommended that the geotechnical engineer, or a qualified geo-technician under his supervision, be retained to provide continuous engineering services during construction of the foundation, excavations, and earthwork phases of the work. This is to observe compliance with the design concepts, specifications, or recommendations and to modify these recommendations in the event that subsurface conditions differ from those anticipated. This report, does not constitute a warranty either expressed or implied, as no one can predict the long-tern changes in subsurface moisture conditions resulting from improper grading, excessive irrigation by the home owner or neighbors or other causes during and after construction.

If you have any questions, or if we may be of further assistance, please do not hesitate to contact us.

Respectfully Submitted:

CAPSTONE ENTERPRISES WEST, LLC

Martin W. Chenoweth, PE

Registered Professional Engineer

MWC